BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B69 10118

SUBJECT: Presentation Made to the S-II POGO Working Group Meeting - Case 320

DATE: October 20, 1969

FROM: A. T. Ackerman

ABSTRACT

A presentation of the Bellcomm analysis of the MSFC S-II Center LOX line test was made to the MSFC POGO Working Group Meeting. The analysis showed that the resonant frequencies of this test line are representative of the flight and are consistent with data generated by Rocketdyne in a different test setup.

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MEMORANDUM FOR FILE

The writer presented the results of the Bellcomm analysis performed with George Reis* of the MSFC S-II Center Engine LOX line test to the POGO Working Group Meeting on October 16, 1969 at MSFC. We undertook this effort to help us understand previously presented test results.

In order to determine the resonant frequency of the S-II Center Engine LOX line, MSFC set up the test facility shown in Figure 1. The flight line is connected between the J-2 LOX pump and the LOX tank sump. The pump is of flight configuration, is driven by a gas generator and feeds a "bobtail" engine (this contains all the inlet plumbing but there is no combustion). The LOX sump is a simulated section of the flight configuration; the LOX is supplied from a facility storage tank via a facility line. The facility accumulator was added in an attempt to isolate the storage tank and line from the simulated sump. The pulser line is an overboard bleed which contains a variable orifice. This variable orifice is a plug-type valve which is stroked at the selected frequency by pneumatic actuation.

The Bellcomm model of this test setup is shown in Figure 2. The components are resistance, inertance and compliance; the variables are pressure and flow. The definition of the terms is shown in the figure.

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*G. Reis, "Analysis of a Test Method for Measuring Resonant Frequencies of Loaded Hydraulic Feedlines", Case 320, Technical Memorandum, to be issued.

We will now proceed to show how the model can be used to examine the effects of individual features of the test setup. Consider first only the line and its terminating impedance. If the pulser produced an oscillatory flow which was constant as a function of frequency, a typical response of the pump inlet pressure would be as shown by the solid curve of Figure 3; This is the true line response and the desired output of the test setup which, unfortunately, contains other effects. Connecting the test facility to the inlet of the test line introduces some source impedance (taken as an inertance) and tends to reduce the frequency of the maximum response, as shown by the second curve of Figure 3. Further the test facility could not maintain a constant pulse amplitude over the frequency range tested, and this effect further reduces the frequency of the maximum response, as shown by the third curve of Figure 3.

To account for the variation of pulse amplitude, the pump inlet pressure P_p should be divided by pulser flow. Since this measurement was not available, MSFC used the pulser pressure P_o (see Figure 2) as an indicator of pulser flow. Figure 4 shows that P_o has a minimum which occurs when the impedance seen looking into the line at P_1 is equal to and opposite the impedance of L_b (see Figure 2). This minimum of P_o affects the frequency of the maximum value of the ratio P_p/P_o.

Therefore, the frequency of the maximum amplitude of the P_p data is affected by the facility source inertance and pulser frequency response. On the other hand, the frequency of the maximum amplitude of the P_p/P_o ratio is affected by the coupled resonance of the pulser line and the test line. The MSFC test setup parameters are such that these several effects tend to cancel each other and the uncorrected MSFC data of P_p/P_o are good measures of the flight line frequency. Even use of the Rocketdyne dual compliance pump impedance does not greatly affect the answer. That is, the spread is within

± 5 percent. This is a significant improvement of previous results, which spread over a factor 2 range.

Figures 5 through 9 are a composite series of our computer results. Curve 1 shows the isolated flight line terminated in a simple pump cavitation; this curve is used as the reference to compare other curves. Curve 2 shows the reduction of frequency by addition of the facility inlet inertance. In order to account for the effect of pump flow, a simple pump inpedance (made up of a series combination of inertance and resistance) was used in parallel with the pump cavitation, and Curve 3 shows that this tends to raise the frequency somewhat. The effect of variable pulser amplitude, Curve 4, again lowers the frequency. Forming the ratio P_p/P_o raises the indicated frequency Curve 5 and is very close to Curve 1.

Rocketdyne performed other tests on a different facility and derived a more complex engine load or pump impedance, Figure 10. As seen in Figure 11, the effect of the additional parts is slight, within 1 Hz or 5% of the reference curve.

Comparing our computer results to the test data, Figure 12, we see that our pump response P_p is narrower than the test data and this is felt to be due to the loss-less nature of our model. Further, there is poor agreement in the low frequency region of the pulser pressure P_o; this is not an easy part of the system to model because the pulser is actually a variable orifice and the pulser line may contain some other subtle features. However, both the computer and test data show a local minimum or dip at 20 Hz which is not too obvious because the pulser amplitude is falling off with frequency. Figure 13 shows the excellent agreement between the test and the computer when the ratio P_p/P_o is plotted.

If physical changes to lengths of lines and locations of pressure measurements are made to the MSFC test facility, pulser pressure minima and maxima should be ascertained to verify that the ratio P_p/P_o is still representative of the line response.

A. T. Ackerman

2031-ATA-ajj

Attachments

S-II LOX FEEDLINE TEST FACILITY

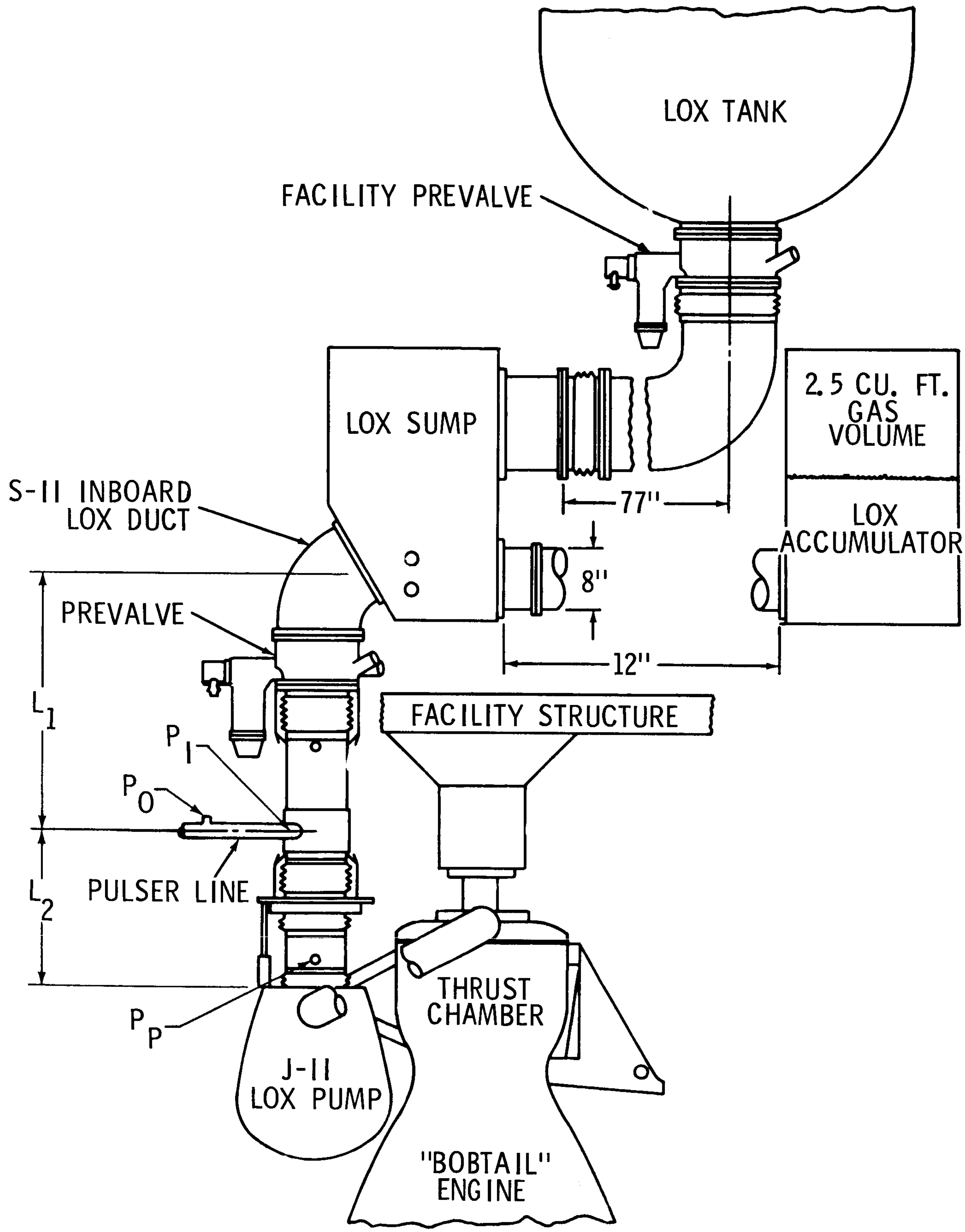
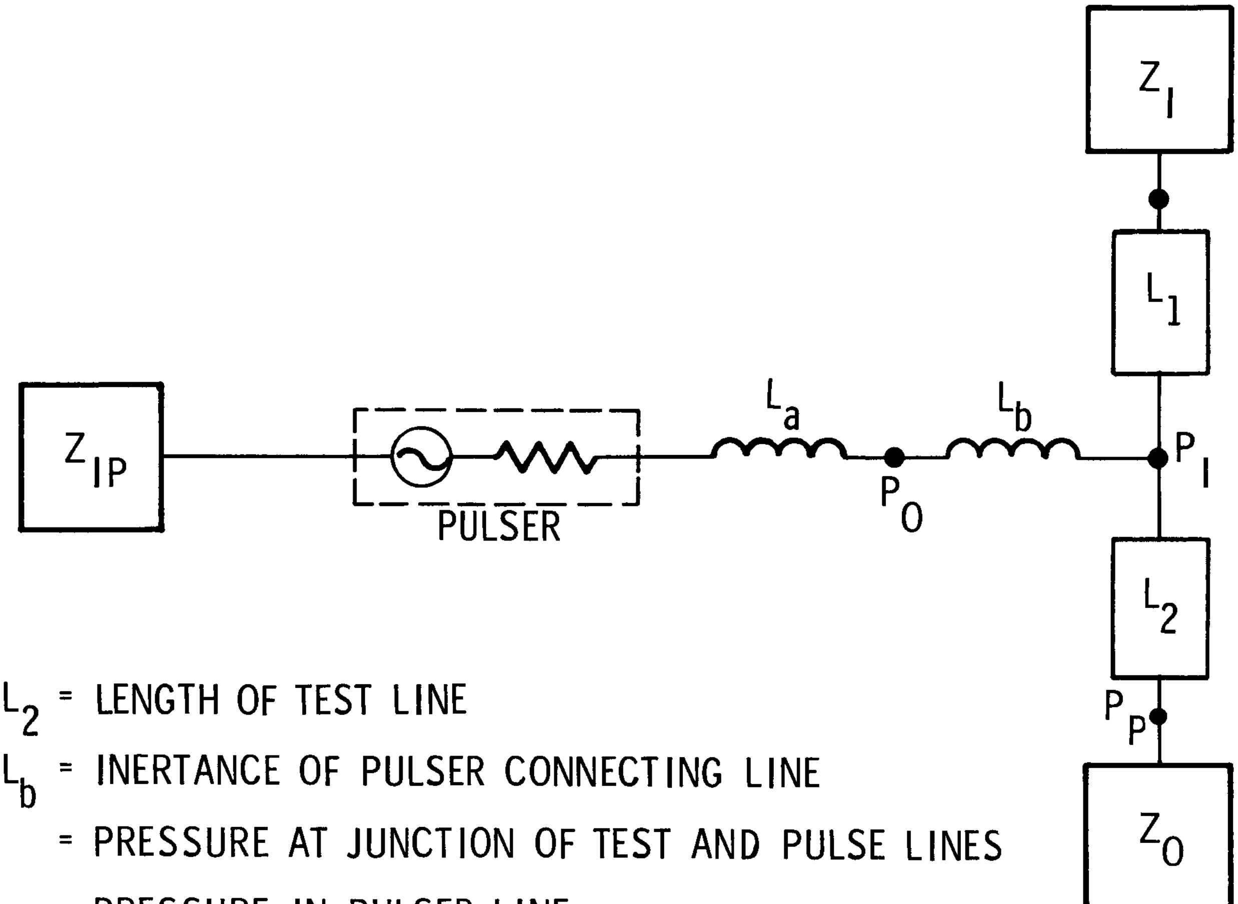


FIGURE 1

S-II LOX FEEDLINE TEST FACILITY SCHEMATIC



L_1+L_2 = LENGTH OF TEST LINE

L_a+L_b = INERTANCE OF PULSER CONNECTING LINE

P_I = PRESSURE AT JUNCTION OF TEST AND PULSE LINES

P_0 = PRESSURE IN PULSER LINE

P_P = PRESSURE AT PUMP

Z_I = IMPEDANCE AT INLET OF TEST LINE DUE TO FACILITY LINES AND ISOLATING ACCUMULATOR

Z_0 = IMPEDANCE AT OUTLET OF TEST LINE DUE TO PUMP IMPEDANCE AND CAVITATION COMPLIANCE

Z_{IP} = PULSER TERMINATING IMPEDANCE DUE TO PULSER DISCHARGE LINE

FIGURE 2

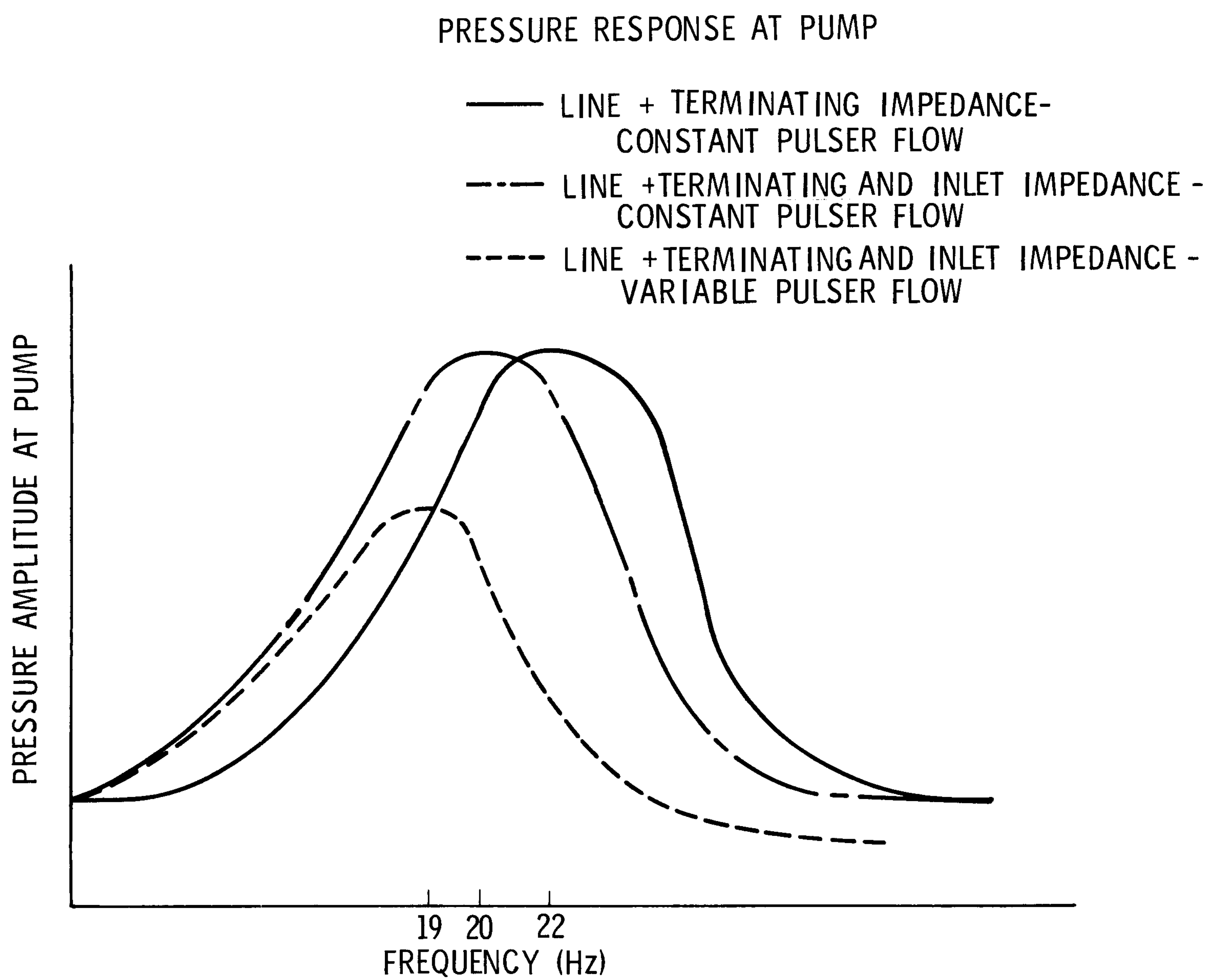

PRESSURE RESPONSE AT PUMP
LINE + TERMINATING IMPEDANCE- CONSTANT PULSER FLOW
LINE +TERMINATING AND INLET IMPEDANCE - CONSTANT PULSER FLOW
LINE +TERMINATING AND INLET IMPEDANCE - VARIABLE PULSER FLOW
PRESSURE AMPLITUDE AT PUMP
19
20
22
FREQUENCY (Hz)

FIGURE 3

S-II LOX LINE RESPONSE

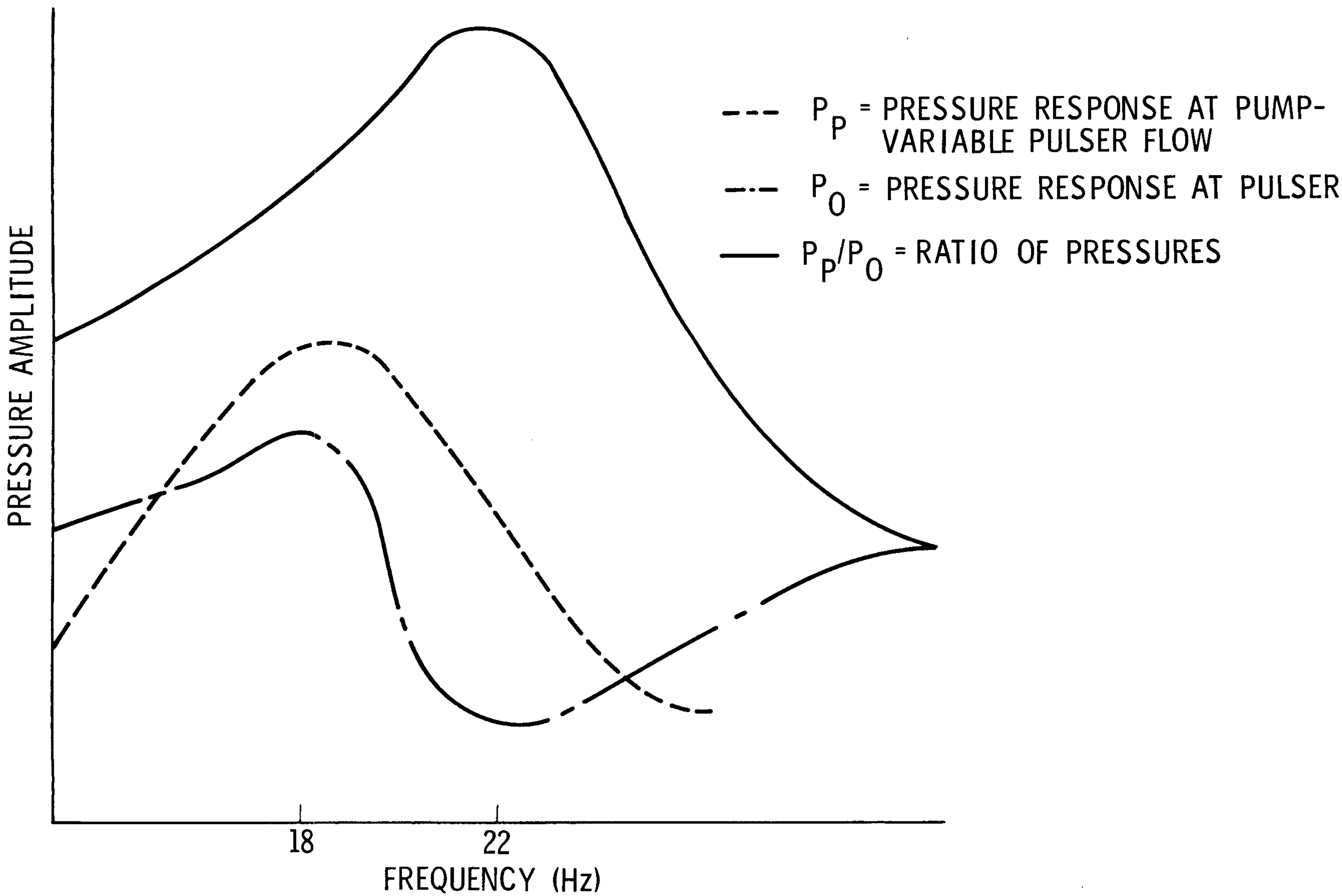


FIGURE 4

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS

1. CAVITATION ONLY

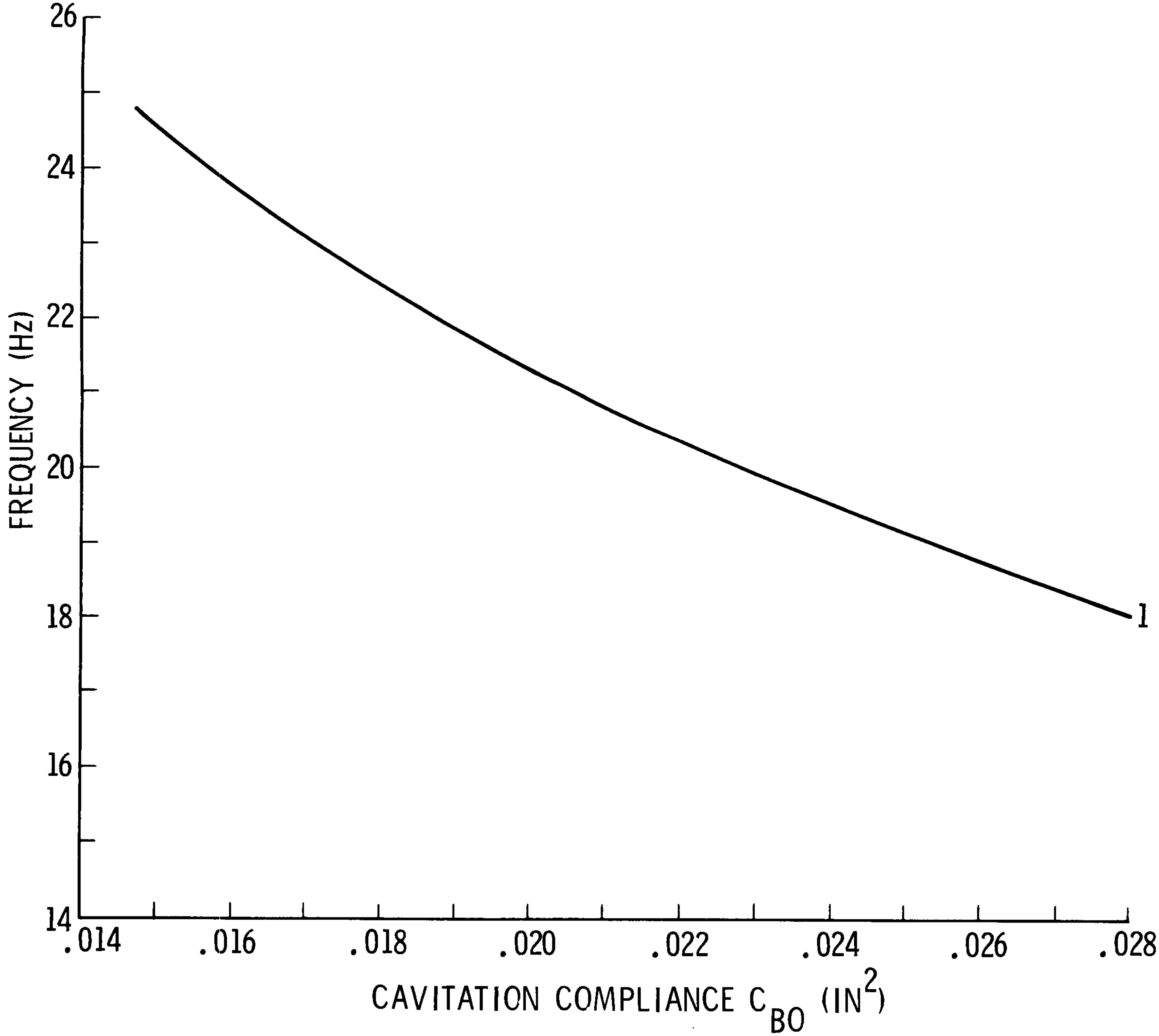


FIGURE 5

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS

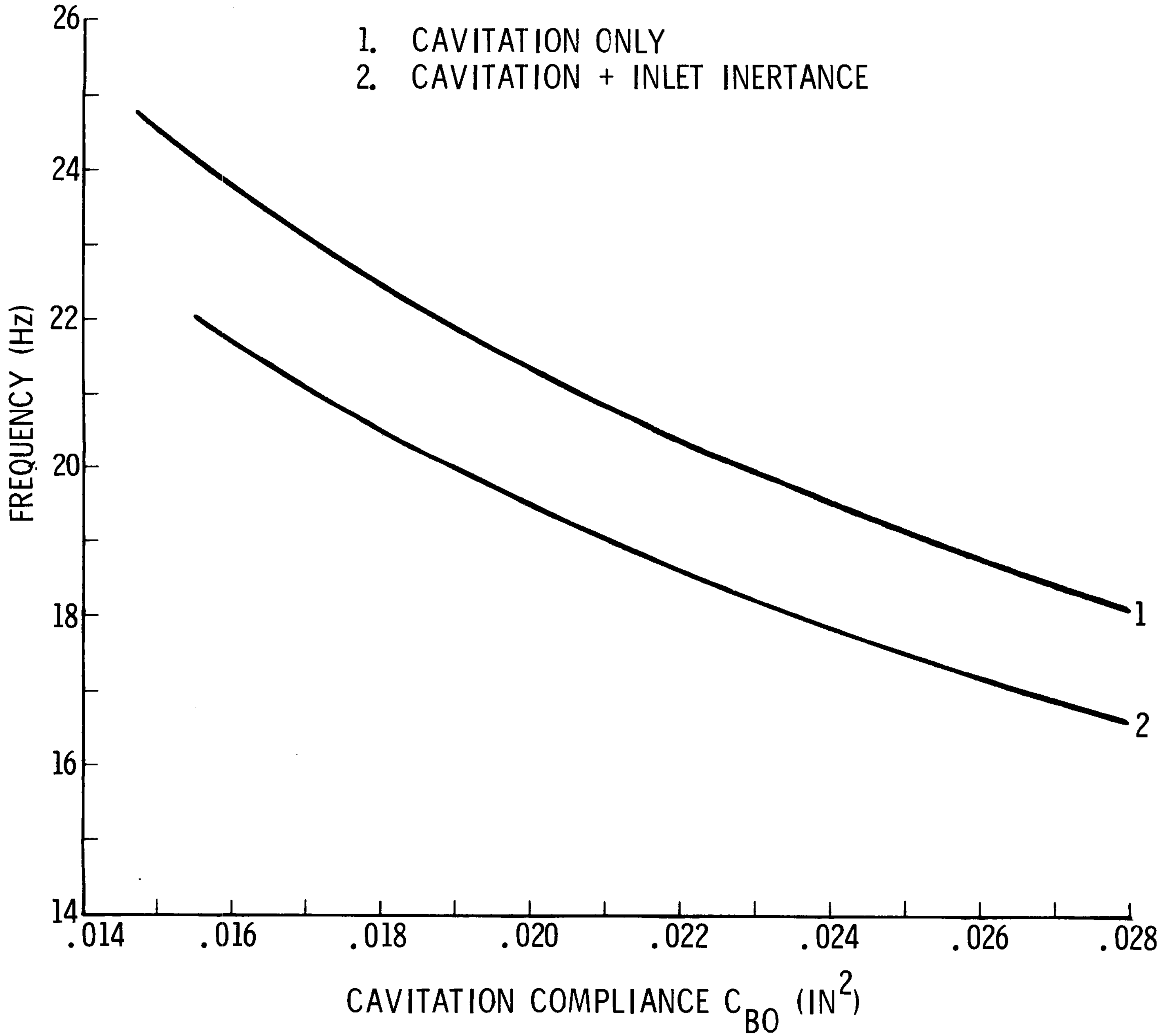


FIGURE 6

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS

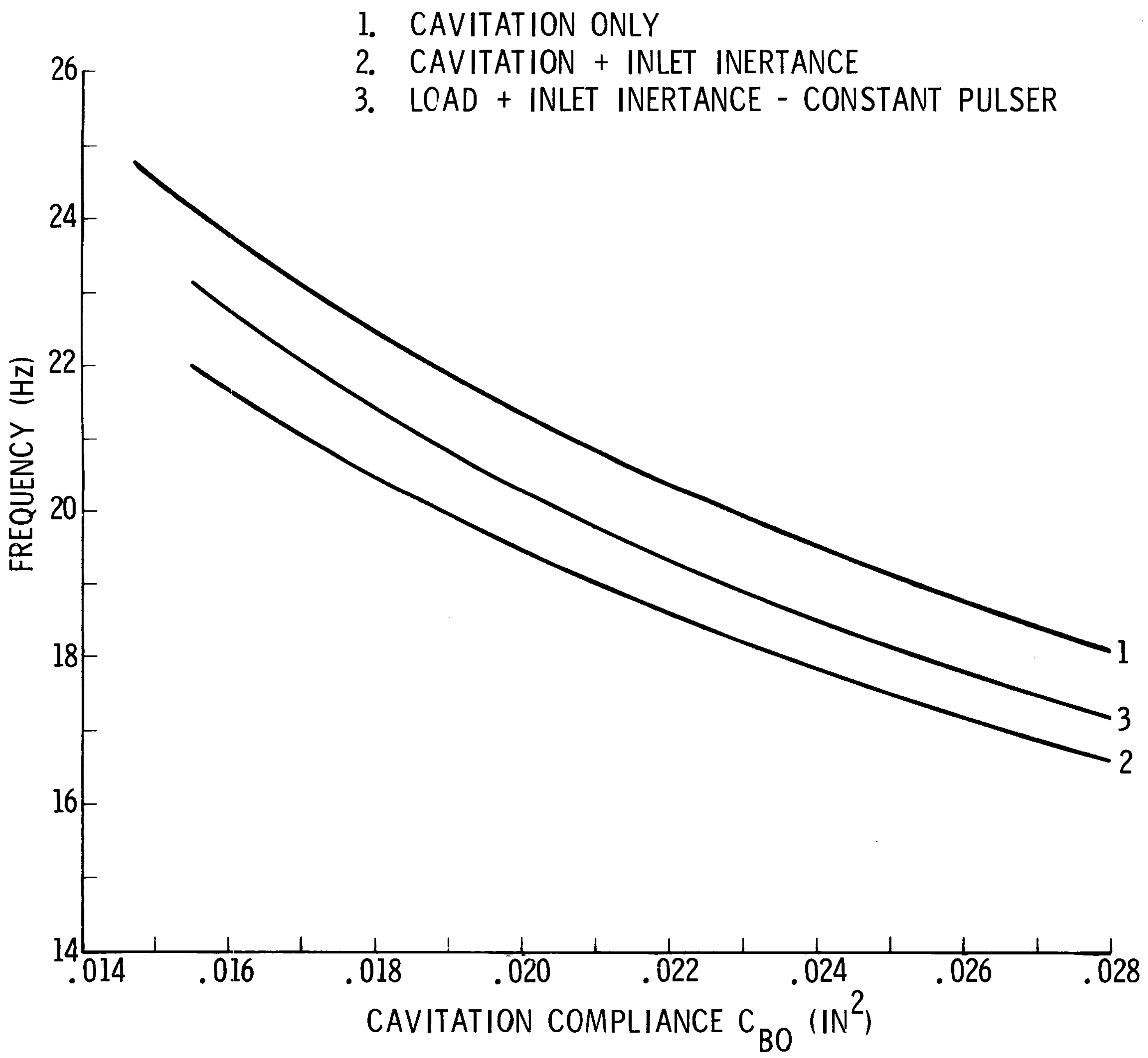


FIGURE 7

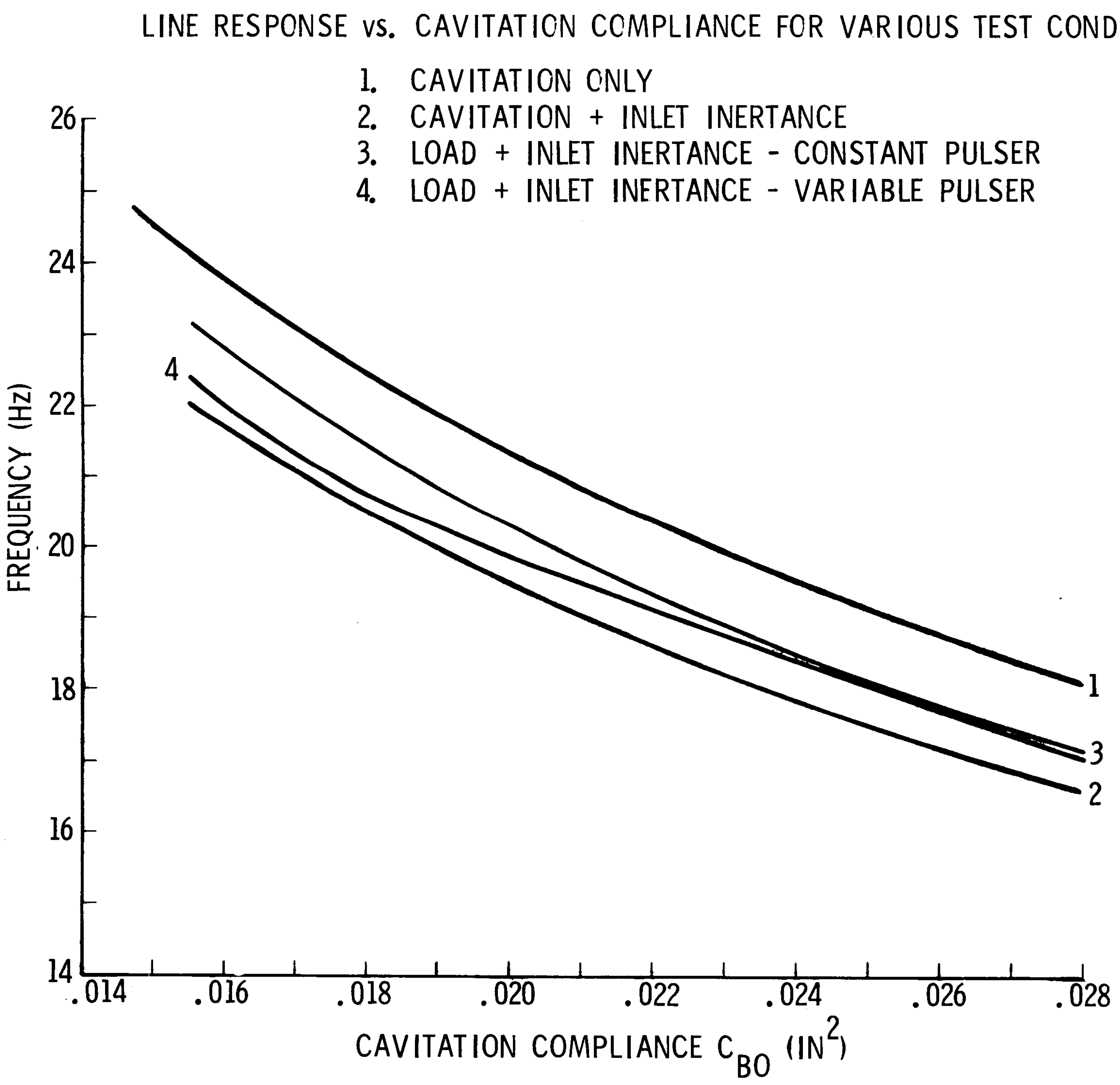

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS
1. CAVITATION ONLY
2. CAVITATION + INLET INERTANCE
3. LOAD + INLET INERTANCE - CONSTANT PULSER
4. LOAD + INLET INERTANCE - VARIABLE PULSER
FREQUENCY (Hz)
26
24
22
20
18
16
14
.014
.016
.018
.020
.022
.024
.026
.028
1
2
3
4
CAVITATION COMPLIANCE C_{BO} (IN^2)

FIGURE 8

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS

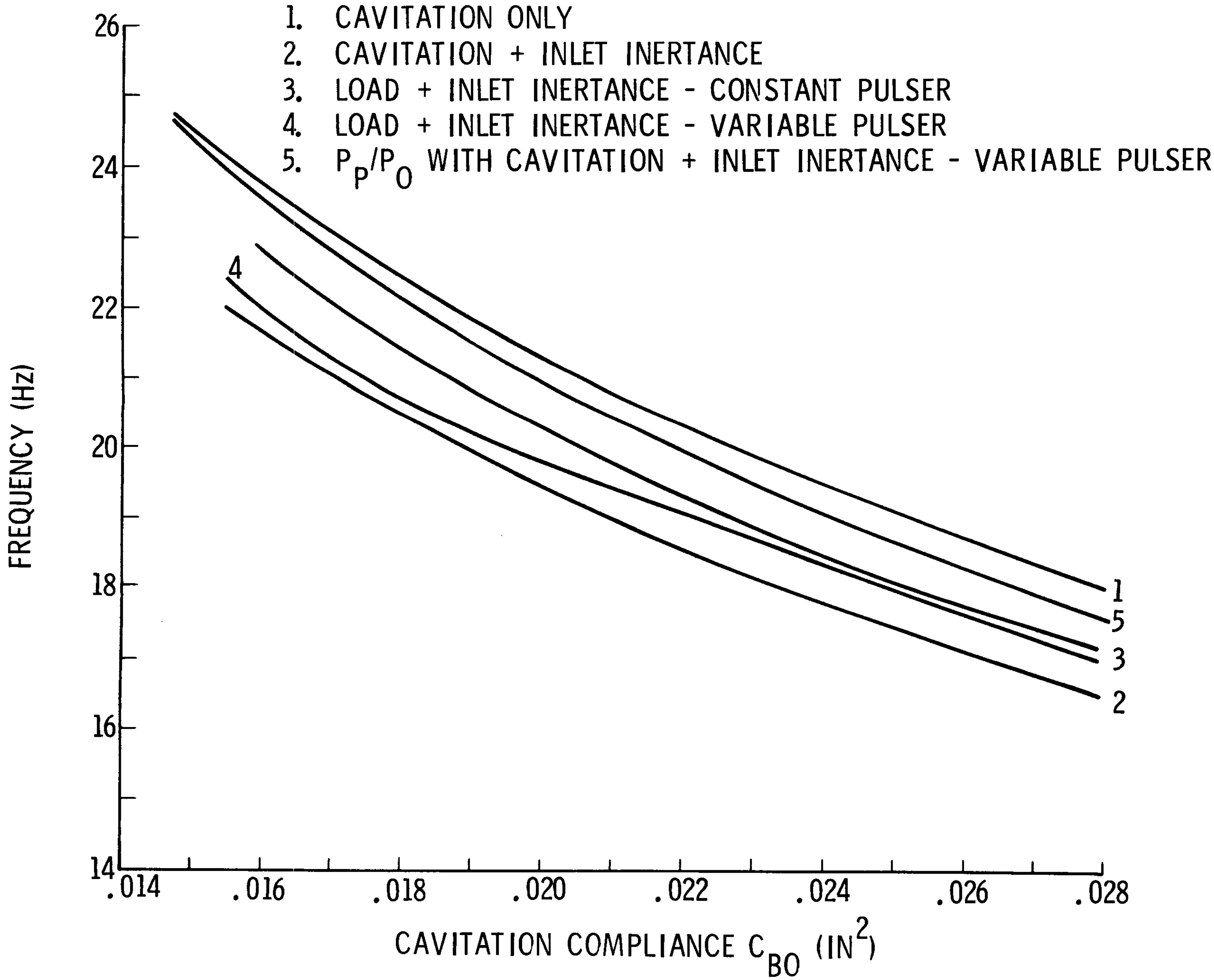
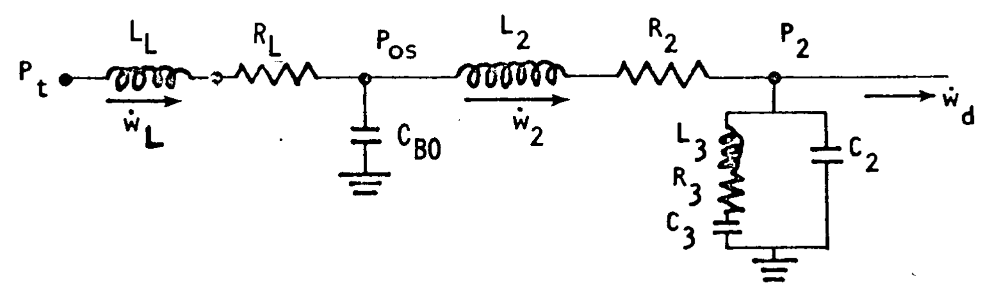
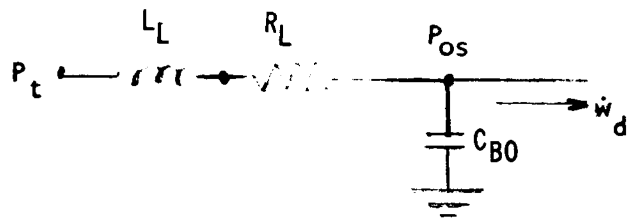


FIGURE 9

COMPARISON OF ENGINE LOADS



DOUBLE COMPLIANT ROCKETDYNE LOAD



SINGLE COMPLIANT ENGINE LOAD

FIGURE 10

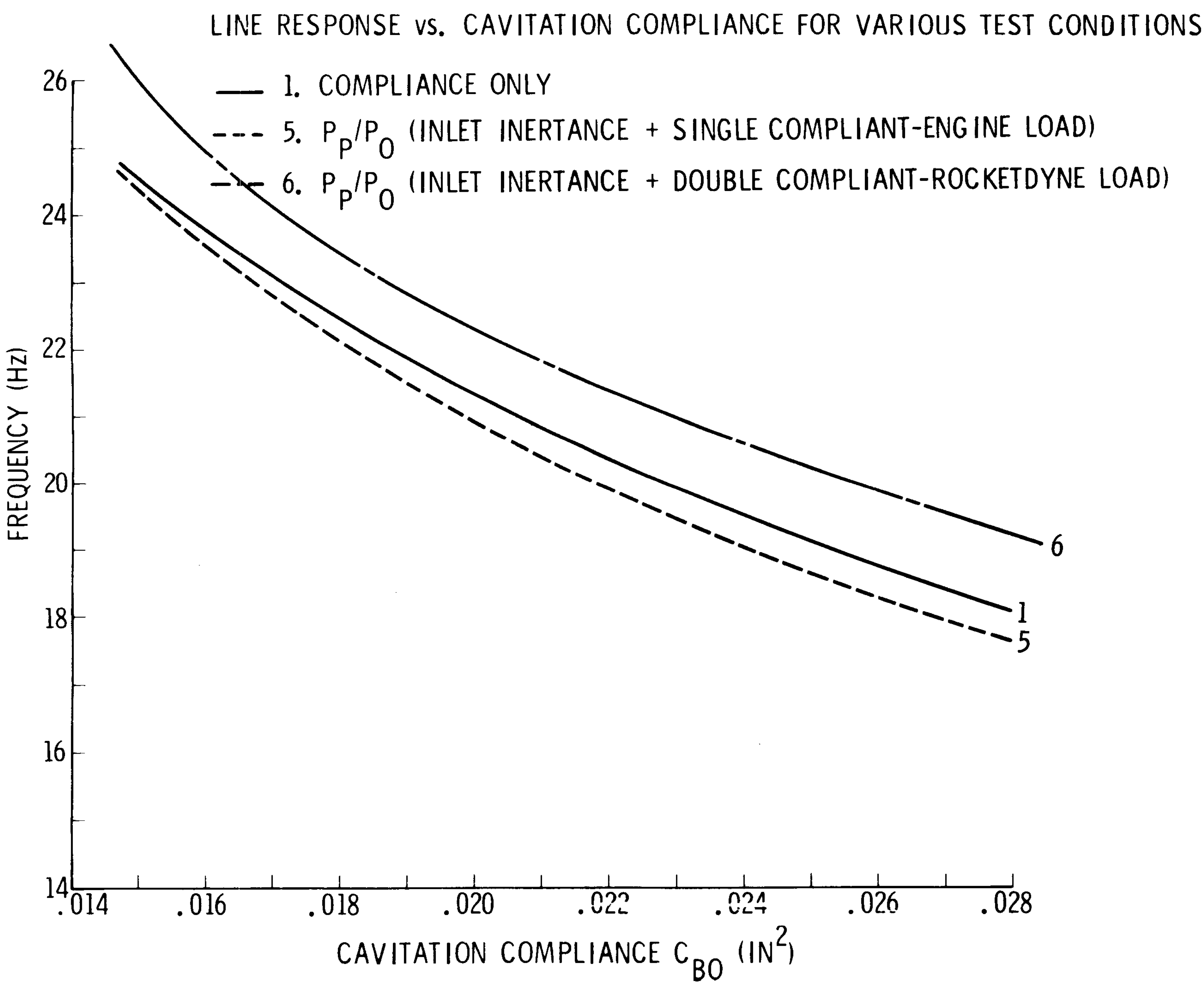

LINE RESPONSE vs. CAVITATION COMPLIANCE FOR VARIOUS TEST CONDITIONS
1. COMPLIANCE ONLY
5. P_P/P_O (INLET INERTANCE + SINGLE COMPLIANT-ENGINE LOAD)
6. P_P/P_O (INLET INERTANCE + DOUBLE COMPLIANT-ROCKETDYNE LOAD)
FREQUENCY (Hz)
26
24
22
20
18
16
14
.014
.016
.018
.020
.022
.024
.026
.028
CAVITATION COMPLIANCE C_{BO} (IN^2)
6
1
5

FIGURE 11

S-II CENTER LOX LINE RESPONSE

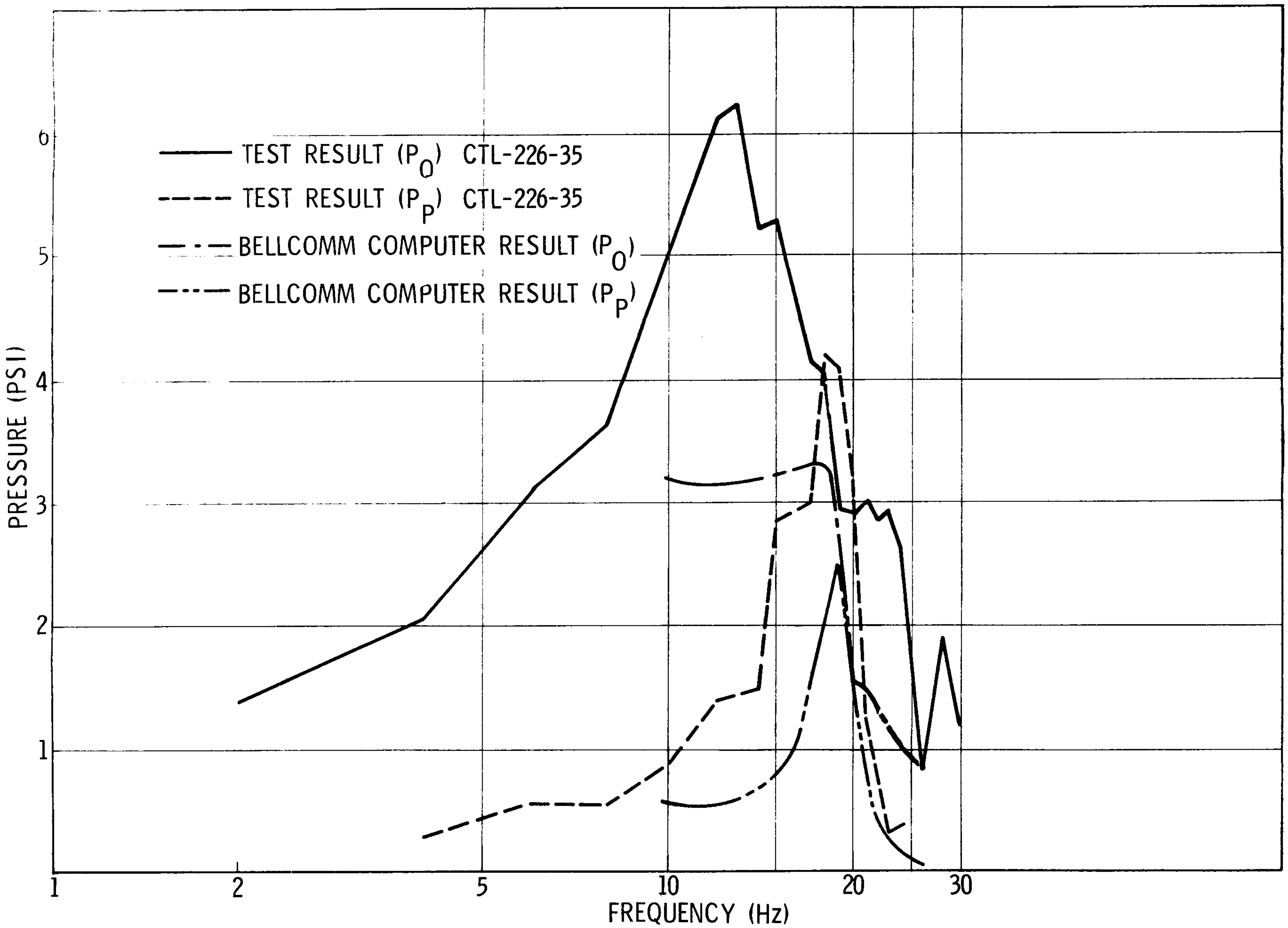


FIGURE 12

S-II CENTER LOX LINE RESPONSE

PUMP PRESSURE / PULSER PRESSURE (P_P/P_O)

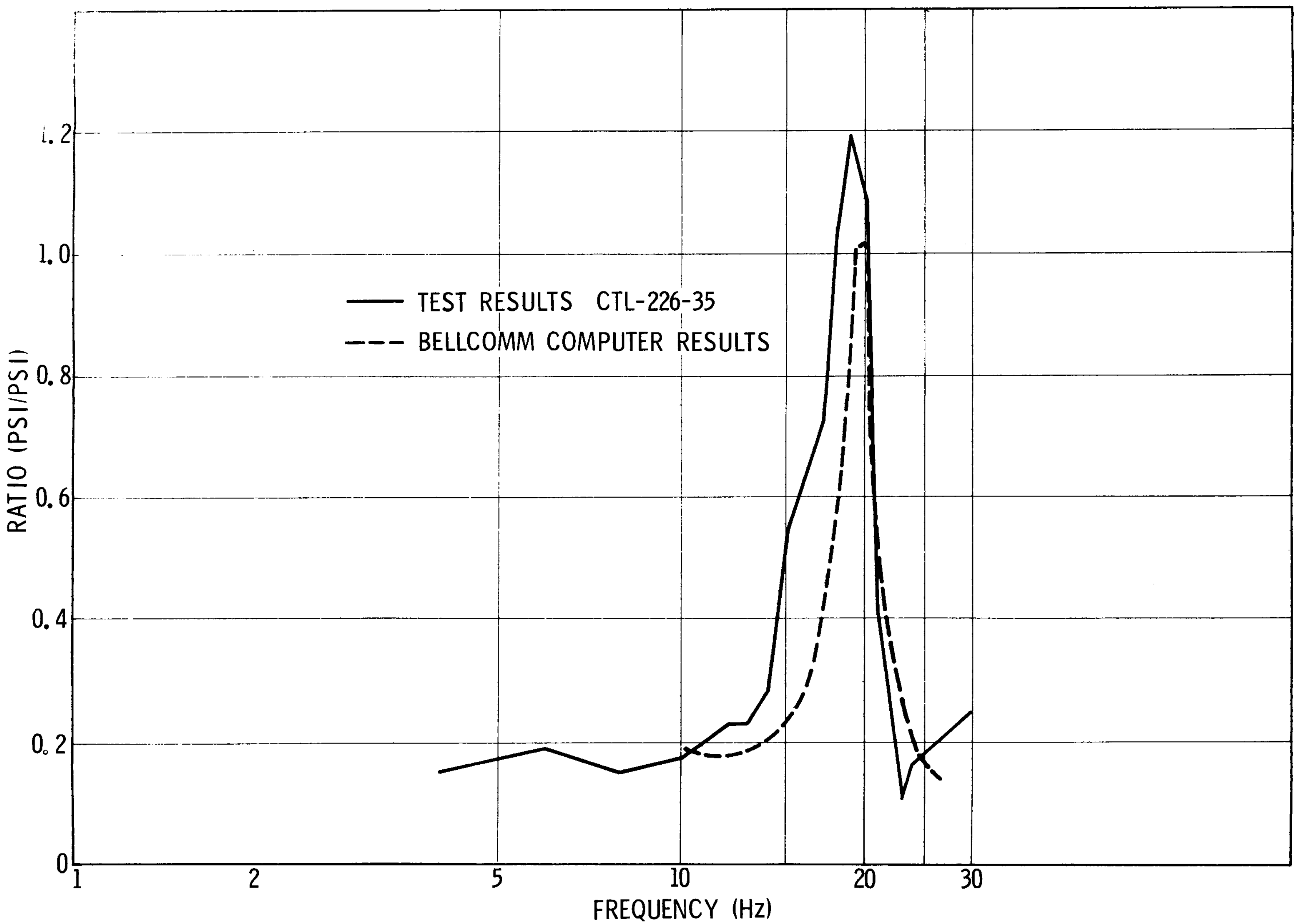


FIGURE 13